COVID in MA analyzer

Introduction and citations

Data sources

I'm using the wiki compilation at https://en.wikipedia.org/wiki/2020_coronavirus_pandemic_in_Massachusetts which gives confirmed cases of COVID-19 in Masachusetts, acording ultimately to the daily updates from the MA Dept of Public Health, such as https://www.mass.gov/doc/covid-19-cases-in-massachusetts-as-of-march-28-2020/download .

Subsidiary factoids:

Population of Boston:

```
pop_yr=[2010, 2017];
pop_pp=[620702,685094];
pop_2020_bos=diff(pop_pp)/diff(pop_yr)*3+pop_pp(2)
```

```
pop_2020_bos = 7.1269e+05
```

Population of Massachusetts:

```
pop_yr=[2005, 2018];
pop_pp=[6.454e6,6.902e6];
pop_2020_ma=diff(pop_pp)/diff(pop_yr)*2+pop_pp(2)
```

```
pop_2020_ma = 6.9709e+06
```

Intent

Just to have an idea of when we should see a peak.

Data sets and structure

Data are given in the table Cov_Ma.

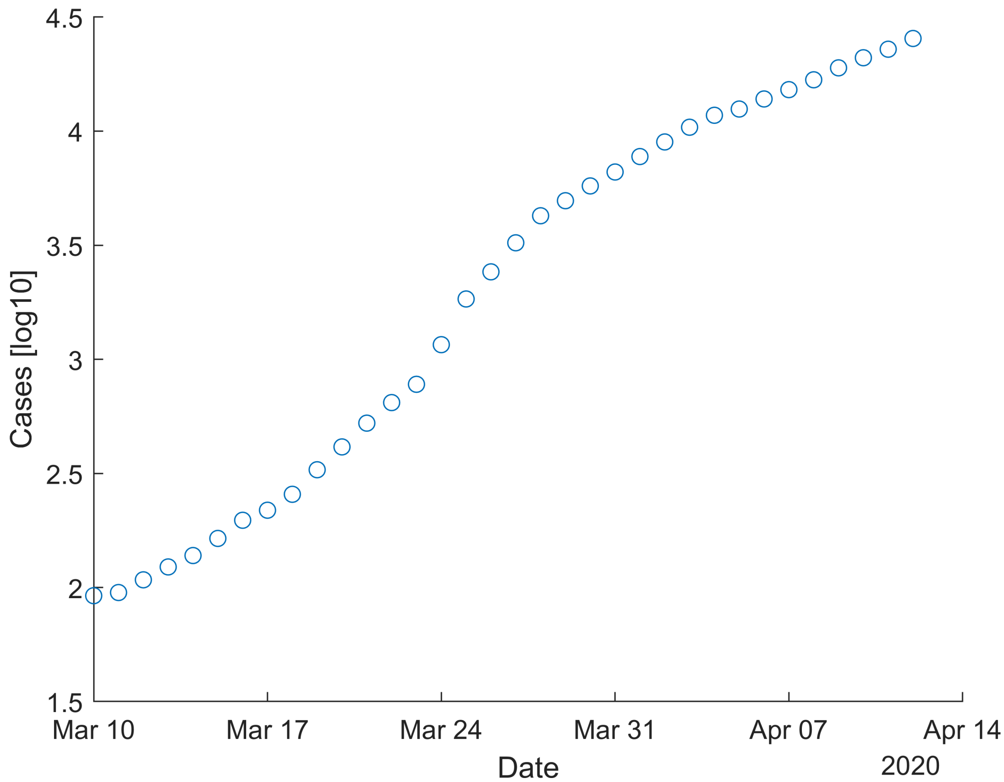
```
Cov_Ma.Properties.VariableNames
```

```
ans = 1×12 cell array

    {'Days_since_Mar_10'}    {'Cases'}    {'Date'}    {'Cases_change'}    {'Cases_growth'}    {'Tests'}    {'Tests_
```

Just the facts, ma'am

```
figure
scatter(Cov_Ma.Date, log10(Cov_Ma.Cases))
ylabel('Cases [log10]')
xlabel('Date')
```



Fitting the data to a logistic curve

The logistic curve is given by

$$m_i = \frac{k_i}{1 + e^{-(t-t_0)\cdot\gamma}}$$

where m_i is a measure of COVID (I use identified cases and identified deaths), t is th enumber of days since March 10 (a reasonble measure of when community spreading started), t_0 is the midpoint of the growth (measured in days since March 10), and γ is a constant related to growth rate.

One must initialize the vector of constants with initial conditions to begin the minimization that finds the best-fitting array of constants.These are determined by trial and error. Good practice is to use a variety of IC to make sure the solution i srobust. The ICs are in array $beta0_i$. MATLAB makes fitting the model pretty easy.

FIts

Cases

```
modelfun_c = @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
modelfun_c = function_handle with value:

    @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
beta0_c = [40000 50 0.05];
mdl_c = fitnlm(Cov_Ma.Days_since_Mar_10,Cov_Ma.Cases,modelfun_c,beta0_c)
```

```
mdl_c =
Nonlinear regression model:
    y ~ F(b,x)

Estimated Coefficients:
          Estimate       SE        tStat       pValue
          ________    _________    ______    __________

    b1      37628        2865.2    13.133    3.3175e-14
    b2     29.658       0.85321     34.76    2.1374e-26
    b3    0.18733     0.0089451    20.942    7.4425e-20

Number of observations: 34, Error degrees of freedom: 31
Root Mean Squared Error: 510
R-Squared: 0.996,  Adjusted R-Squared 0.996
F-statistic vs. zero model: 4.3e+03, p-value = 1.1e-40
```

Deaths

```
modelfun_d = @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
modelfun_d = function_handle with value:

    @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
beta0_d = [100 20 0.222];
mdl_d = fitnlm(Cov_Ma.Days_since_Mar_10,Cov_Ma.Deaths,modelfun_d,beta0_d)
```

```
mdl_d =
Nonlinear regression model:
    y ~ F(b,x)

Estimated Coefficients:
          Estimate       SE       tStat       pValue
          ________    ________    ______    __________

    b1     1572.7       182.62    8.6119     1.001e-09
    b2      33.22      0.91209    36.422    5.1975e-27
    b3    0.23283     0.010343    22.512    9.0423e-21

Number of observations: 34, Error degrees of freedom: 31
Root Mean Squared Error: 11.8
R-Squared: 0.997,  Adjusted R-Squared 0.997
F-statistic vs. zero model: 5.3e+03, p-value = 4.32e-42
```

Predictions

```
Pred_window=21;
Pred_days=0:max(Cov_Ma.Days_since_Mar_10)+Pred_window;
Pred_dates=(min(Cov_Ma.Date):days(1):max(Cov_Ma.Date)+days(Pred_window))';
[Cov_Ma_Pred.cases, Cov_Ma_Pred.casesci]=predict(mdl_c,Pred_days','Prediction','observation');
[Cov_Ma_Pred.deaths, Cov_Ma_Pred.deathsci]=predict(mdl_d,Pred_days','Prediction','observation')
```

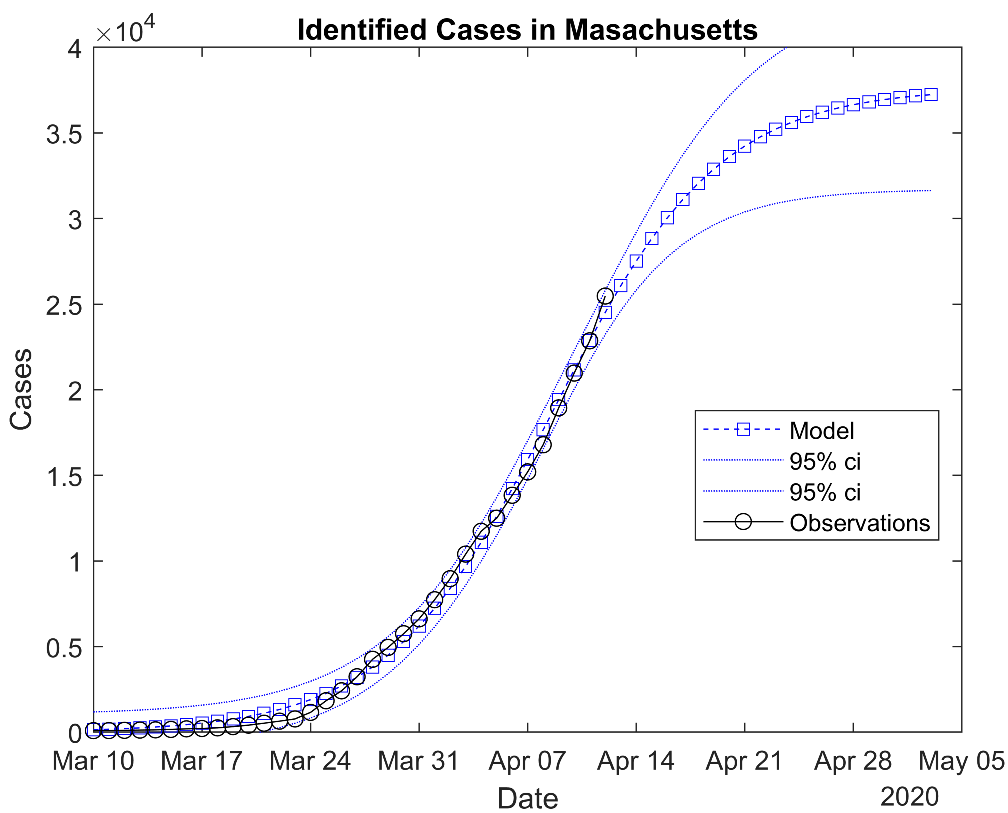
Graph the data and the models up

Cases

```
figure
plot(Pred_dates,Cov_Ma_Pred.cases,'--bs')
hold
```

```
Current plot held
```

```
plot(Pred_dates,Cov_Ma_Pred.casesci(:,1),':b')
plot(Pred_dates,Cov_Ma_Pred.casesci(:,2),':b')
plot(Cov_Ma.Date,Cov_Ma.Cases, '-ko')
ylabel('Cases')
xlabel('Date')
ylim([0,40000])
title('Identified Cases in Masachusetts')
legend('Model','95% ci','95% ci','Observations', 'location', 'best')
```

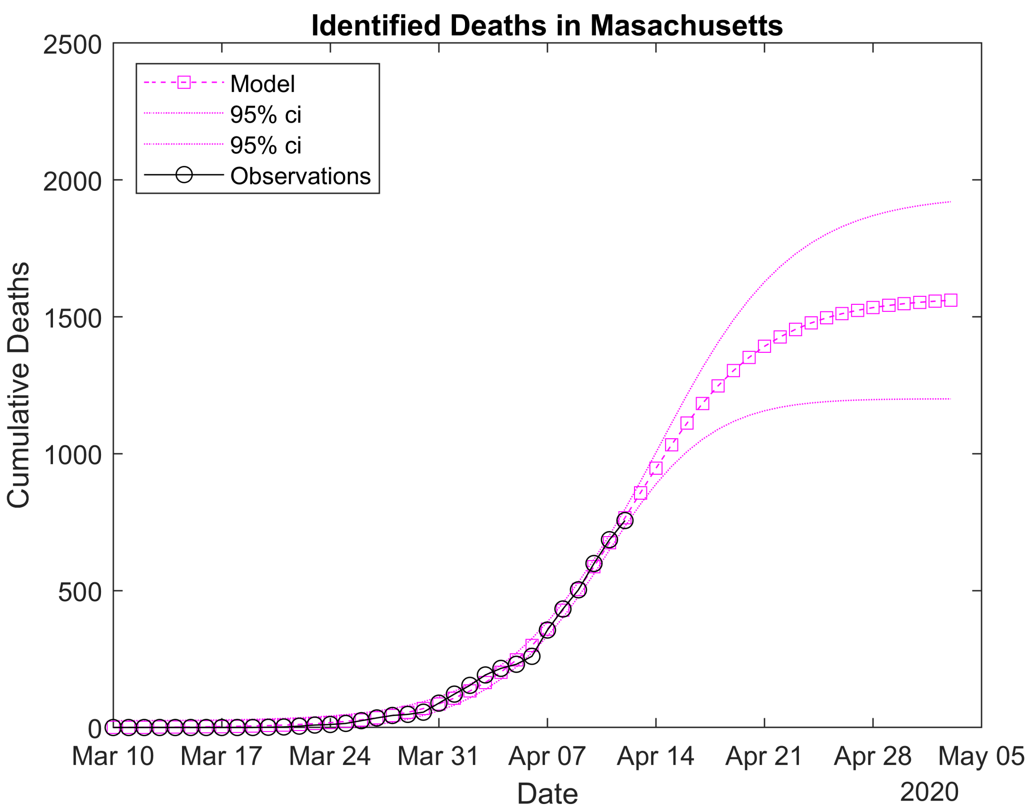


Deaths

```
figure
plot(Pred_dates,Cov_Ma_Pred.deaths,'--ms')
hold
```

```
Current plot held
```

```
plot(Pred_dates,Cov_Ma_Pred.deathsci(:,1),':m')
plot(Pred_dates,Cov_Ma_Pred.deathsci(:,2),':m')
plot(Cov_Ma.Date,Cov_Ma.Deaths,'-ko')
ylabel('Cumulative Deaths')
xlabel('Date')
ylim([0,2500])
title('Identified Deaths in Masachusetts')
legend('Model','95% ci','95% ci','Observations', 'location', 'best')
```



When are the peaks?

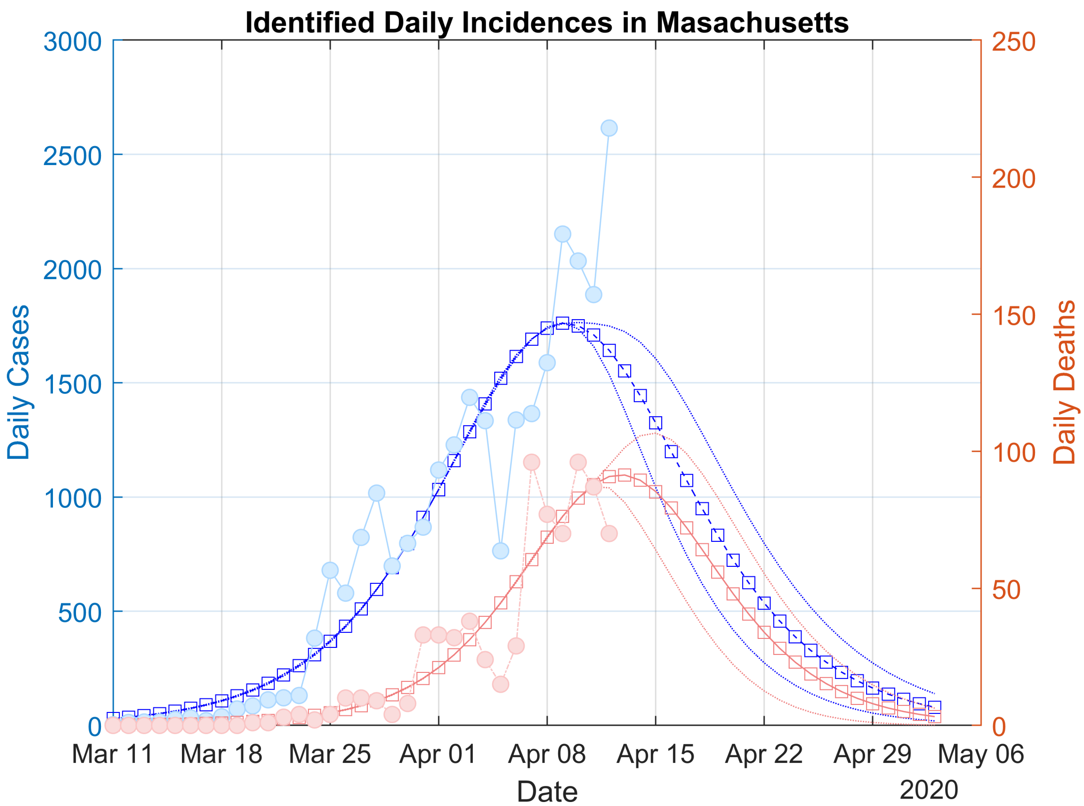
Take the differences in the cumulative graphs and plot them up to see the peaks.

```
figure
yyaxis right
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.deaths),'Color', [.94 .5 .5], 'LineStyle','-', 'Marker
hold
```

```
Current plot held
```

```
grid
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.deathsci(:,1)),'Color', [.94 .5 .5], 'LineStyle',':')
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.deathsci(:,2)),'Color', [.94 .5 .5], 'LineStyle',':')
plot(Cov_Ma.Date(2:end),diff(Cov_Ma.Deaths),'Color', [.98 .78 .78], 'MarkerFaceColor',[.98 .88
ylabel('Daily Deaths')
xlabel('Date')
```

```
ylim([0,250])
title('Identified Daily Incidences in Masachusetts')
%legend('Model','95% ci','95% ci','Observations', 'location', 'best')
yyaxis left
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.cases),'--bs')
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.casesci(:,1)),':b')
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.casesci(:,2)),':b')
plot(Cov_Ma.Date(2:end),diff(Cov_Ma.Cases),'Color', [.68 .85 1], 'MarkerFaceColor', [.84 .92 1
ylabel('Daily Cases')
```




```
%xlabel('Date')
%ylim([0,50])
%title('Identified Daily Incidences in Masachusetts')
%legend('Model','95% ci','95% ci','Observations', 'location', 'best')
```

Using previous results to predict the short-term future

Just the numbers

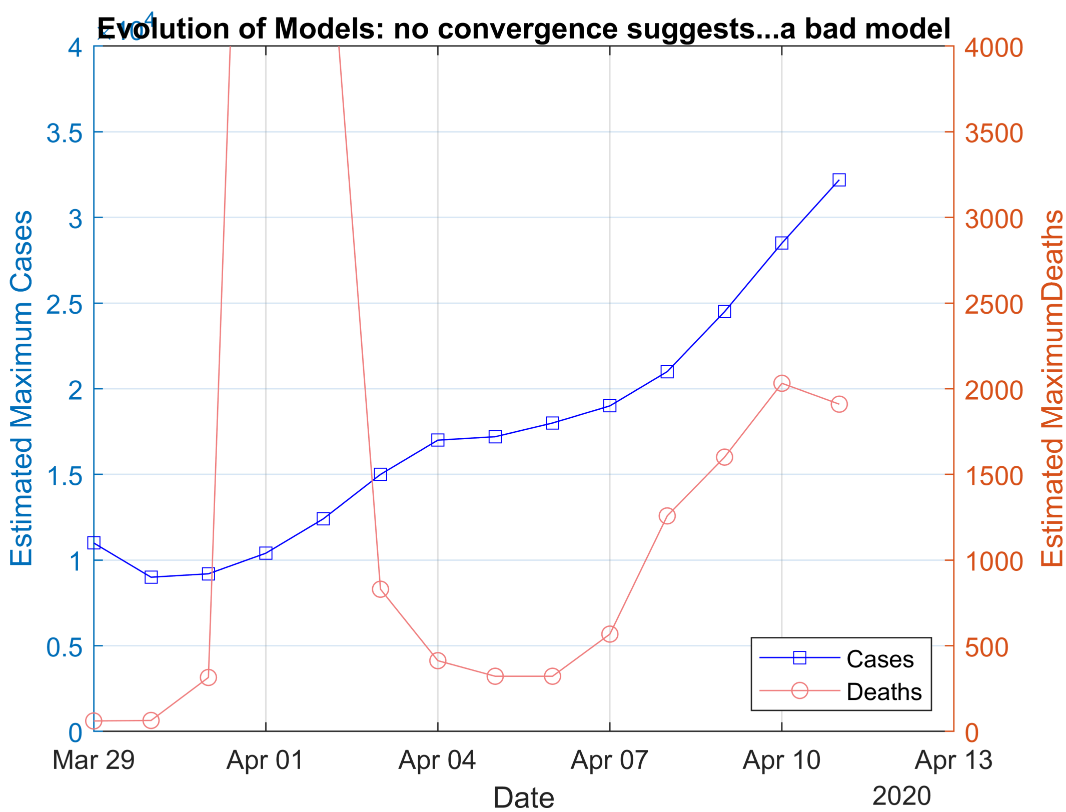
```
figure
yyaxis left
plot(beta0time.Date,beta0time.k_cases,'-bs')
ylabel('Estimated Maximum Cases')
xlabel('Date')
ylim([0,40000])
title('Evolution of Models: no convergence suggests...a bad model')
```

```
hold
```

```
Current plot held
```

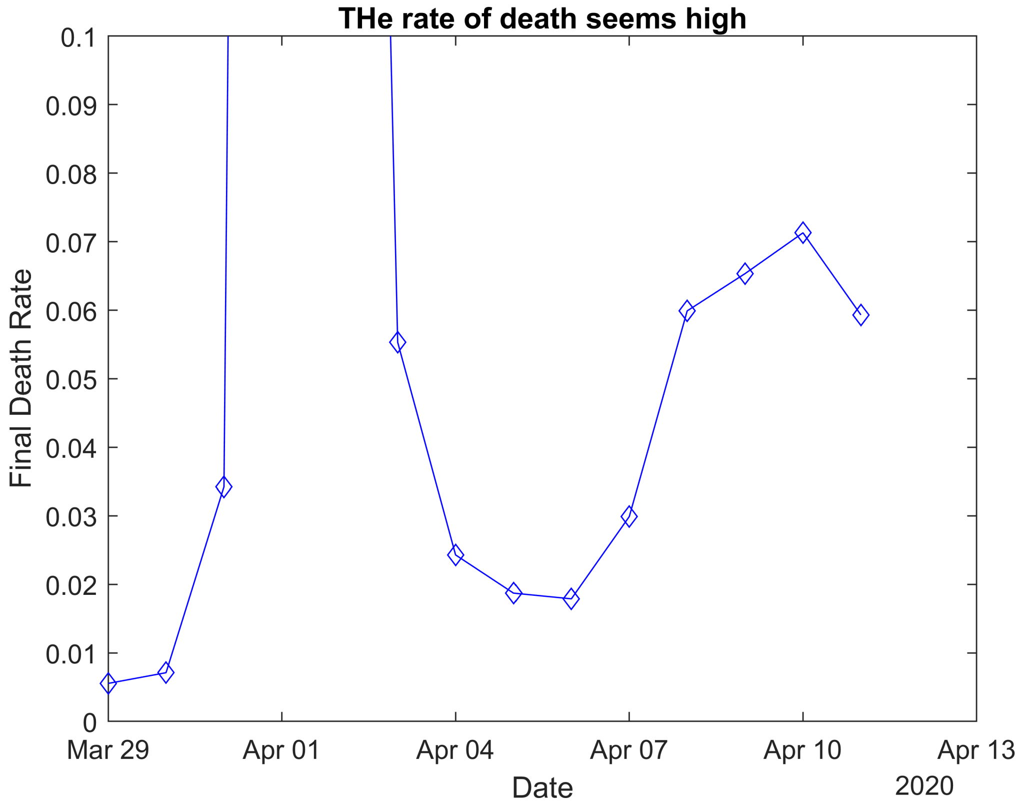
```
grid
yyaxis right
plot(beta0time.Date,beta0time.k_deaths,'Color', [.94 .5 .5], 'LineStyle','-', 'Marker','o')
ylabel('Estimated MaximumDeaths')
xlabel('Date')
ylim([0,4000])

legend('Cases', 'Deaths', 'location', 'southeast')
```



Ratio: death rate,

```
figure
plot(beta0time.Date,beta0time.k_deaths./beta0time.k_cases, '-bd')
ylabel('Final Death Rate')
xlabel('Date')
ylim([0,0.1])
title('THe rate of death seems high')
```



This high rate is most likely due to unidentified cases, which has been typical. Assume that the death rte in Massachusetts has been ~1.6%, we can identify the total case load: